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(71) Applicant: ZUCOTTO WIRELESS, INC. [US/US]; 4225 Executive Square, Suite 400, La Jolla, CA 92037 (US).

(72) Inventor: COMEAU, Guillaume; 60 du Meteore Hull, Quebec, Quebec J9A 3B5 (CA).

(74) Agent: WARDAS, Mark; 4225 Executive Square, Suite 400, La Jolla, CA 92037 (US).

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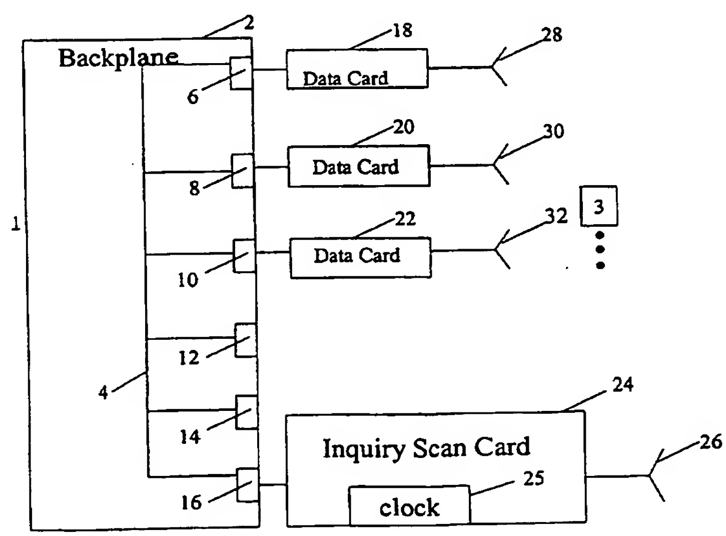
(54) Title: ACCESS POINT FOR WIRELESS COMMUNICATIONS



(57) Abstract: An access point (1) includes a backplane having a clock interface and a plurality of slots for accepting an inquiry scan card (24) and a plurality of data cards. The inquiry scan card (24) detects an inquiry transmitted by a master wireless device within the range of communication with the access point (1) and transmits an inquiry response to the master wireless device to signify an intent to establish a wireless data link. The inquiry scan card (24) selects one of the data cards to establish the data link with the master wireless device and sends a message to the selected data card to wait for a connection request transmitted by the master wireless device. Upon detecting the connection request, the selected data card transmits a connection response to the master wireless device and sets itself in an active mode for a bi-directional data link with the master wireless device.

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ACCESS POINT FOR WIRELESS COMMUNICATIONS

Field of the Invention

The present invention relates to communications, and more particularly, to an access point used in wireless communications.

Background Art

Short-range wireless digital communications systems are being developed for voice, video and data communications using radio frequency (RF) signals. An industry standard which has been developed for short range wireless digital communications is the Bluetooth™ specification, which is a technical specification for a frequency hopping time division multiplexed (TDM) wireless system operating in a radio frequency range of 2.400 GHz to 2.4835 GHz in the United States. A conventional Bluetooth™ wireless network typically includes a plurality of Bluetooth™ communication devices, each having a unique Bluetooth™ address and an independent clock. Data links are established between the Bluetooth™ devices in a typical "piconet" configuration. Within a typical piconet, one of the Bluetooth™ devices acts as the "master" while other Bluetooth™ devices act as "slaves." One of the slave devices within a particular piconet is capable of acting as a master for another piconet, which includes one or more additional slave devices.

Within a typical piconet, the master device has a master clock and a unique frequency hopping sequence (FHS), which is derived from the Bluetooth™ address of the master device. All of the slave devices within the piconet are synchronized with the clock and the frequency hopping sequence of the master device. In a typical sequence for establishing a data link between a master device and a slave device, the slave device is initially set in an idle mode while the master device is initially set in an inquiry scan mode.

Before a wireless connection is established, a wireless device is not pre-designated either as a master or as a slave. Whether a wireless device acts as a master or as a slave depends on whether it initiates a connection to establish a wireless data link with another wireless device. The Bluetooth specification also allows a master/slave switch to occur once a connection has been established between two devices. A typical Bluetooth™ inquiry includes a determination of whether a particular wireless device is within the range of communication and the addresses of wireless devices within the range. For example, if a master device intends to initiate communications with a particular access point, it may

send an inquiry to the access point, which, upon receiving the inquiry, sends an inquiry response back to the master device. The access point is then set in a connection request scan mode to wait for a connection request from the master device. After the master device receives the inquiry response from the access point, it sends a connection request to the access point, and upon receiving the connection request from the master device, the access point sends a connection response back to the master device. The access point and master device are then both set in an active mode to establish a bi-directional data link between the access point and master device.

At this point the access point is a slave to a master device since the master device is the one that initiated the connection. In a piconet there is no slave- to- slave communication. For the access point to support other connections, it must initiate a slave/master switch.

Although a master device is theoretically capable of communicating with multiple slave devices within a typical piconet using time division multiplexing, several problems arise in practical situations in which at least some of the slave devices are mobile wireless devices and the number of slave devices intending to establish data links within the range of communication with the master device are not fixed. Because the total data throughput of a typical Bluetooth™ piconet has an aggregate data rate of roughly 1Mb/s, a problem arises when multiple slave devices move into the piconet and intend to establish data links with the master device of the piconet. The inclusion of additional slave devices within a piconet results in less bandwidth per slave device. Another problem typically associated with multiple slave devices within a piconet is that piconet clocks tend to drift relative to each other, thereby resulting in degradations in synchronization.

Furthermore, as additional slave devices move into the range of communication of the master device within a given piconet intending to establish data links with the master device, connection latency becomes a problem in a conventional time division multiplexed wireless system. Significant time delays may occur for additional slave devices, which intend to establish data links with the master device of the piconet if the master device already bears the burden of maintaining time division multiplexed communications with a plurality of existing slave devices. In an attempt to resolve the problems of synchronization and connection latency, highly complicated software, which includes nested complex state machines, have been implemented in conventional Bluetooth™

wireless devices. However, even with highly complicated software, interruptions caused by multiple slave devices requesting data links, and the resulting connection latency still exists as a significant problem in existing Bluetooth™ networks.

The problem of synchronization becomes especially troublesome when multiple piconets are interconnected in a typical Bluetooth™ wireless network. For example, any one of a plurality of slave devices in a first piconet may serve as the master of a second piconet. When it operates as a slave device of the first piconet, it is synchronized on the master clock and the frequency hopping sequence of the master device of the first piconet. However, as the master of the second piconet, this device uses its own frequency hopping sequence derived from its own Bluetooth™ address. The clock of this device is used to synchronize the slave devices within the second piconet. The piconet clocks may drift with respect to each other, thereby causing the time slots of the frequency hopping sequences of the first and second piconets to be aligned incorrectly, unless complicated software is implemented to resolve the conflict of frequency hopping sequences caused by the drifting of piconet clocks in a conventional Bluetooth™ wireless network.

Therefore, there is a need for an access point 1 which is capable of handling data traffic with multiple wireless devices with increased data throughput while reducing the connection latency if additional wireless devices seek to establish data links with the access point 1. Furthermore, there is a need for an access point 1 which is capable of maintaining stable synchronization while obviating the need for complicated software to resolve potential conflicts of time slots of different frequency hopping sequences.

Summary of the Invention

The present invention provides an access point, generally comprising: a plurality of data circuits for mastering a plurality of piconets, each of the data circuits having a unique address and capable of performing a connection response upon detecting a connection request to establish a data connection; and an inquiry scan circuit connected to the data circuits, the inquiry scan circuit capable of detecting an inquiry, and upon detecting the inquiry, performing an inquiry response and sending a message to one of the data circuits to wait for the connection request.

The present invention also provides a method of wireless communication, generally comprising the steps of: detecting an inquiry transmitted by a wireless device; transmitting an inquiry response to the wireless device; selecting one of a plurality of data

circuits to establish a data connection with the wireless device; detecting a connection request transmitted by the wireless device; and transmitting a connection response to the wireless device.

Advantageously, the available bandwidths for data links with multiple wireless devices can be increased while the connection latency for establishing additional data links with additional wireless devices can be reduced in embodiments according to the present invention. Furthermore, stable synchronization can be maintained with multiple time division multiplexed data links while obviating the need for implementing complicated state machine software.

These as well as other aspects of the invention discussed above may be present in embodiments of the invention in other combinations, separately, or in combination with other aspects and will be better understood with reference to the following drawings, description, and appended claims.

Brief Description of the Drawings

The present invention will be described with particular embodiments thereof, and references will be made to the drawings in which:

FIG. 1 shows a diagram of an access point 1 for a wireless network in an embodiment according to the present invention;

FIG. 2 shows a diagram of an embodiment of one of the data cards implemented in the access point 1 of FIG. 1;

FIG. 3 shows a diagram of an embodiment of an inquiry scan card 24 implemented in the access point 1 of FIG. 1;

FIG. 4 illustrates a method of establishing a data link in a wireless network in an embodiment according to the present invention;

FIG. 5 shows a flowchart illustrating an embodiment of the initial procedure of inquiring the information of each data card of the access point 1; and

FIG. 6 shows a diagram illustrating an embodiment in which each data card serves as the master of a piconet which may include one or more devices.

Detailed Description

FIG. 1 shows a diagram of an embodiment of an access point 1 in a wireless communications network, such as a Bluetooth™ network. Although embodiments of the

present invention will be described with reference to a Bluetooth™ network, the present invention is also applicable to other types of wireless networks.

In one embodiment, an access point, for example, a wireless access point 1 may comprise a connector or backplane 2 which has a plurality of connections or slots 6, 8, 10, 12, 14 and 16. A plurality of circuits 18, 30, 32 may be connected to at least some of the slots of the backplane through interfaces which may include data interfaces 5 (see Figs 2-3) and a common clock interface 4. In the embodiment shown in FIG. 1, the access point 1 may include a plurality of circuits, which may be implemented as data circuits on data cards 18, 20 and 22, which may connected to slots 6, 8 and 10, respectively, of the backplane 2. Additional slots 12 and 14 may be available on the backplane 2 to accept additional data cards whenever necessary or desirable, thereby providing flexibility and scalability to the access point 1 for handling multiple data links with at least one device 3 of at least one Bluetooth™ piconet. In one embodiment, the device 3 may comprise a wireless device, for example, a cellular phone, personal digital assistant (PDA), computer. Other devices 3 are understood to fall within the scope of the present invention.

As shown in FIG. 1, an inquiry scan circuit is implemented as an inquiry scan card 24 and is connected to the card slot 16 of the backplane 2. In one embodiment, the inquiry scan card 24 includes a clock 25, which provides a common clock reference signal to all of the data cards connected to the backplane 2 as well as to the inquiry scan card 24 itself. The common clock signal generated by the clock 25 may be transmitted from the inquiry scan card 24 to the data cards 28, 30 and 32 through the common clock interface 4 on the backplane 2. Alternatively, the common clock reference signal may be generated by an external source and provided to the data cards and the inquiry scan card 24 through the common clock interface 4 on the backplane 2.

Although FIG. 1 illustrates one embodiment of the access point 1 which utilizes a modular design with separate connections and circuits for scalability, other physical implementations are contemplated and are within the scope of the present invention. For example, the backplane 2, the data cards and the inquiry card can all be merged onto one printed circuit board (PCB) or a similar circuit board structure. Also, although various embodiments discussed herein may be implemented with cards, it is understood that in other embodiments other technologies for implementing circuits are within the scope of the present invention, for example, chips, modules, etc. Futhermore, the backplane 2 may

be considered to comprise a switching subsystem between a plurality of access or control elements, which may be implemented by those skilled in the art in embodiments other than described herein. Thus, other embodiments are within the scope of the description that follows.

The inquiry scan card 24 maybe capable of detecting an inquiry transmitted by a master wireless device 3 which desires to establish a data link with the access point 1 within the range of communication with the access point 1. Upon detecting the inquiry, the inquiry scan card 24 may select the least busy data card and generates an inquiry response on behalf of that data card, using that data card's Bluetooth™ address and clock phase to compose the Bluetooth™ frequency hopping sequence (FHS) packet. It then may transmit the inquiry response to the master device 3 to signify that the particular data card of the access point 1 intends to establish a data link with the master device.

Before transmitting the inquiry response to the master device 3, the inquiry scan card 24 may send a message to the selected data card through the backplane 2 to wait for a connection request, which is expected to be transmitted by the master wireless device 3 after it receives the inquiry response from the inquiry scan card 24. Embodiments for establishing a data link between the access point 1 and a master wireless device 3 within a Bluetooth™ piconet will be described in further detail below with reference to FIG. 4.

In FIG. 1, the inquiry scan card 24 is equipped with a transmit and receive antenna 26 for receiving an inquiry scan from a master wireless device 3 which desires to establish a data link with the access point 1. The antenna 26 is also capable of transmitting an inquiry response to the master wireless device 3 signifying the intent of the access point 1 to establish a data link between the access point 1 and the master wireless device 3.

If an additional master wireless device 3 transmits an inquiry to look for an access point 1 within its range of communication, the inquiry scan card 24 may detect this inquiry if the additional master wireless device 3 is in fact within the range of communication with the access point 1. The inquiry scan card 24 may select one of the data cards 18, 20 and 22 to wait for a connection request transmitted by the additional master wireless device 3, and may transmit an inquiry response to the additional master wireless device 3.

In one embodiment, the inquiry scan card 24 may assign more than one master wireless device 3 to the same data card or to different data cards depending upon the existing communication load of each of the data cards. For example, if the inquiry scan

card 24 determines that data cards 18 and 20 are each handling traffic with several master wireless devices 3 while data card 22 is handling traffic with only one master wireless device 3, the inquiry scan card 24 may assign an additional master wireless device 3 to data card 22, such that none of the data cards 18, 20 and 22 is overloaded with data traffic. In a wireless communications network using time division multiplexing, such an arrangement may provide adequate bandwidth for each of the master wireless devices 3 within the range of communication with the access point 1. In one embodiment, each of the data cards is also equipped with a transmit and receive antenna for receiving a connection request transmitted by a master wireless device 3 which intends to establish a data link with the access point 1, as well as transmitting a connection response upon detecting the connection request to signify to the master wireless device 3 that the data card intends to establish a data link with the master wireless device 3. As shown in FIG. 1, the data cards 18, 20 and 22 may be equipped with transmit and receive antennas 28, 30 and 32, respectively. After the master wireless device 3, which intends to establish a data link with the access point 1 receives the desired connection response from the selected data card, radio frequency (RF) signals carrying digital data are transmitted and received bi-directionally by the antennas of the selected data card and the master wireless device 3. In a typical Bluetooth™ network, the master wireless device 3 may be a Bluetooth™ equipped laptop computer, mobile telephone, pager, or other device, for example.

In one embodiment, after one of the data cards of the access point 1 establishes a connection with a master wireless device, the master device may retain its master status. In one embodiment, a data card may initiate a slave/master switch to become the master of a piconet. In one embodiment, a data card may initiate a slave/master switch after requested by an inquiry card 24, with the inquiry card 24 requesting a switch on one of the data cards only if all the data cards are slaves to active piconets, at which point, the inquiry card 24 may determine which data card will become a master in order to serve two or more master devices 3.

Referring to FIG. 1, the common clock interface 4 may provide a clock reference not only to all of the data cards 18, 20 and 22 and the inquiry scan card 24, but also to all of the master wireless devices 3 within one of the piconets mastered by a data card. Each of the data cards 18, 20 and 22 has a unique address and a unique frequency hopping sequence that may be derived from its address. Furthermore, the frequency hopping

sequence of each of the data cards has a phase that may be derived from the address of the data card and the common clock signal.

In a similar manner, once a master wireless device 3 establishes a data link with one of the data cards of the access point 1, the master wireless device 3 may also be synchronized by the common clock signal provided on the backplane 2 of the access point 1. In a typical Bluetooth™ network, for example, the frequency hopping sequence of a master device 3 may reflect that of the selected data card of the access point 1 that communicates with the master device 3.

In one embodiment in which an access point 1 communicates with a plurality of master wireless devices 3, the master wireless devices 3 may have bi-directional data links with at least one of the data cards of the access point 1. If, however, the inquiry scan card 24 determines that the communication loads of the data cards are unbalanced, that is, some of the data cards handle more data links than others, the inquiry scan card 24 may reassign the data cards for wireless data connections with the master devices 3 to balance the communication loads among the data cards, assuming that the master wireless devices 3 have substantially equal service priorities or bandwidth demands. If some of the master devices 3 have higher service priorities than others, then load balancing may be performed in such a manner that adequate bandwidths are reserved for master devices 3 with higher service priorities.

When an additional master wireless device 3 moves into the range of communication with the access point 1, the inquiry scan card 24 may determine which one of the data cards is most suitable to accept a new wireless data connection upon receiving the inquiry from the additional master wireless device 3, and may assign the most suitable data card to detect a connection request from the additional master wireless device 3. For example, if one of the data cards is an idle data card while all other data cards are already handling data traffic with existing master wireless devices 3, then the idle card is the one most suitable to accept the new wireless data connection with the additional master wireless device 3 moving into the range of communication with the access point 1. As another example, if all of the data cards are already assigned to handle data traffic with existing master wireless devices 3, then the data card handling the least number of data links is the one most suitable to accept the new wireless data connection with the additional wireless master device 3.

In one embodiment, the inquiry scan card 24 inquires the address of each of the data cards connected to the slots of the backplane 2 upon boot-up. In a further embodiment, the inquiry scan card 24 is also capable of downloading software to upgrade the data cards during the boot-up. Initially, all of the data cards are set in an idle mode before the inquiry scan card 24 detects any inquiry from any of the master wireless devices 3. After a slave/master switch, each of the data cards of the access point 1 may operate as an independent master wireless device except that detecting inquiries and transmitting inquiry responses are performed by the inquiry scan card 24.

FIG. 2 shows a diagram of one embodiment of a data card connected to one of the slots of the backplane 2 of the access point 1 of FIG. 1. Referring to FIG. 2, the data card may comprise a central processing unit (CPU) 34, a baseband circuit 36, for example, a Bluetooth compatible baseband circuit, and a radio transceiver 38. The baseband circuit 36 is connected to the backplane 2 clock interface 4, which feeds the common clock signal to the baseband circuit. The CPU 34 is connected to a backplane 2 data interface 5. The common clock signal is provided to the baseband circuit of each of the data cards for the access point 1. The data card may also store embedded software 40, including, algorithms for synchronization, generation of frequency hopping sequences, and control of time slots for time division multiplexing, as well as other data transfer functions for execution by the CPU 34.

In a forward direction for transmission, the baseband circuit 36, which is connected to the CPU 34, may convert digital signals generated by the CPU 34 into baseband signals for upward frequency conversion by the radio transceiver 38. The radio transceiver 38, which is connected between the baseband circuit 36 and the antenna 42, may perform traditional functions of modulation, demodulation, amplification and filtering. In the reverse direction for reception, the baseband circuit 36 may convert signals received by the radio transceiver 38 into digital signals for processing by the CPU 34.

FIG. 3 shows a diagram of one embodiment of the inquiry scan card 24, which is connected to the backplane 2 clock interface 4. In the embodiment shown in FIG. 3, the inquiry scan card 24 includes a clock 25 which provides a common clock reference signal to not only the inquiry scan card 24 itself but also all the data cards connected to the slots 6, 8, 10, 12, 14 of the backplane 2. Alternatively, the common clock signal may be provided to the inquiry scan card 24 and the data cards by an external clock source.

As shown in FIG. 3, the inquiry scan card 24 may comprise a CPU 44, a baseband circuit 46, for example, a Bluetooth compatible baseband circuit, a radio transceiver 48 and an antenna 50. The baseband circuit 46 of the inquiry scan card 24 has a clock input connected to receive the common clock signal from the clock 25. Furthermore, the clock 25 also feeds the common clock signal to the data cards through the backplane 2 clock interface 4. The CPU 44 of the inquiry scan card 24 is connected to the backplane 2 data interface 5 to communicate with the data cards. In one embodiment, the backplane 2 data interface 5 and the backplane 2 clock interface 4 are provided by card slot 16 of the backplane 2 as shown in FIG. 1.

Referring to FIG. 3, embedded software 52 in the inquiry scan card 24 may include algorithms which may be executed by the CPU 44 to process an inquiry detected by the radio transceiver 48 and to generate an inquiry response based upon the inquiry. In one embodiment, the CPU 44 determines which one of the data cards connected to the backplane 2 of the access point 1 is the most suitable for establishing a wireless data connection with the master device 3 which has transmitted the inquiry. The CPU 44 of the inquiry scan card 24 may then transmit a message through the backplane 2 data interface 5 to the most suitable data card which is selected for establishing a wireless data connection with that master wireless device 3.

In one embodiment, the inquiry scan card 24 may comprise a physical interface used as a bearer to internet protocol (IP) to a private network or the public internet, by implementing either a wired connection such as an Ethernet connection or a long range, high data rate radio link using technology such as general packet radio services (GPRS), universal mobile telecommunications system (UMTS) or wideband- code division multiple access (W-CDMA). In this embodiment, the inquiry scan card 24 may serve as an uplink card to access the private network or the public Internet.

In one embodiment, a physical interface bearing the Internet protocol may be provided as another circuit, for example, as a circuit on an additional data card that may be coupled to communicate over the backplane 2. In this embodiment, the inquiry scan card 24 may query the data card for type as well as addressing information during the boot-up of the data card. The data card may serve as an uplink card to access the private network or the public Internet. The physical interface may be realized with either wired or wireless connections.

The data card which has access to a private network or the public Internet may be used as a gateway to any information, which is not stored locally on the access point 1 or which is not reachable to any one of the master devices 3 in communication with any one of the data cards of the access point 1.

In one embodiment, each of the data cards may contain version information for the software stored in the data card. Upon boot up, the inquiry scan card 24 may query version information from the data cards, validate the version using the uplink card and may update the software for the data card if the software version needs to be updated.

In one embodiment, a second card of the access point 1 may include a physical interface used as a bearer to Internet protocol to serve as a backup uplink card. The backup uplink card with the physical interface bearing the internet protocol may be capable of accessing a secondary network, such as another private network, to provide redundancy in case the first card with the physical interface becomes inoperative. The backup uplink card may be either an inquiry scan card 24 or a data card.

The inquiry scan card 24 may also perform additional functions such as load balancing. For example, the CPU 44 of the inquiry scan card 24 may send requests through the backplane 2 data interface 5 to the data cards to obtain information on the communication loads of the data cards. The information on the communication load of each data card may include, for example, the number of active wireless data links with existing master wireless devices 3, the number of master wireless devices 3 to which wireless data links have dropped dead, and priority information such as the quality of service (QoS) and the class of service (CoS) of each of the master wireless devices 3 maintaining data links with the data card.

The information on the communication loads of the data cards may be received by the CPU 44 of the inquiry scan card 24 through the backplane 2 data interface 5. If the CPU 44 determines that the communication loads among the data cards are unbalanced, it may send messages to the data cards through the backplane 2 data interface 5 to reassign the data cards for wireless data connections with existing master wireless devices 3, such that the available bandwidths of the data cards are efficiently utilized. If some of the master devices 3 have higher service priorities than others based upon their QoS or CoS, then adequate bandwidths may be reserved for data cards maintaining data links with master devices 3 which have higher service priorities, while lower priority master devices

3 may need to share a data card with less available bandwidth. If all of the data cards are already overloaded, some of the data links with low priority master devices 3 may be dropped.

In one embodiment, the CPU 44 of the inquiry scan card 24 may be capable of receiving updated software which is provided to the CPU either externally or through the backplane 2 data interface 5 during boot-up. In addition to setting the data cards in an idle mode after boot-up, the CPU 44 of the inquiry scan card 24 may also be capable of upgrading the software in the data cards during boot-up if a command is received by the CPU 44 of the inquiry scan card 24 to transfer the software to upgrade the data cards.

Because the data cards may be plugged into or out of the slots of the backplane 2, during each boot-up, the addresses of the data cards connected to the backplane 2 of the access point 1 may be different. The CPU 44 of the inquiry scan card 24 may send a message to the data cards during each boot-up to inquire the address of each of the data cards connected to the backplane 2, to ensure that any given one of the data cards is capable of establishing a data link with a master wireless device 3 using the correct frequency hopping sequence derived from the address of the data card.

FIG. 4 illustrates one embodiment of a method of establishing communications between the access point 1 and a master wireless device 3 using standard Bluetooth™ protocols. Although the embodiment of FIG. 4 assumes that at least one of the data cards is initially in the idle mode, one or more of the data cards may be already in the active mode if other master wireless devices 3 are already communicating with them, although the illustration of FIG. 4 assumes that at least one of the data cards is initially in the idle mode. The data card may have an active data link with another master device 3 and still be able to accept new wireless data links.

The inquiry scan card 24 may be set in the inquiry scan mode after boot-up, staying in the inquiry scan mode after it has assigned one of the data cards to establish a wireless data connection with a master wireless device 3, to detect additional inquiries by other master devices 3 which desire to establish data links with the access point 1. The master device 3 in FIG. 4 may send inquiries periodically in an attempt to find an access point, which is willing to establish a wireless data connection with the master device 3. When the master wireless device 3 moves into the range of communication of the access

point 1, the inquiry transmitted by the master device 3 may be detected by the inquiry scan card 24, which has been set in the inquiry scan mode.

Upon detecting the inquiry by the master device 3, the inquiry scan card 24 of the access point 1 selects one of the data cards and sends a message through the backplane 2 to the selected data card for establishing a wireless data link with the master device 3. The data card may be selected according to criteria described above, for example, whether an idle data card is available, which one of the data cards has the least number of active data links, or which one of the data cards has data links only with master devices 3 that have low service priorities. After the data card is selected, the inquiry scan card 24 may transmit an inquiry response to the master device 3 on behalf of the selected data card, to signify to the master device 3 that the selected data card of the access point 1 is ready to accept a data link with the master device 3.

When the selected data card receives the message from the inquiry scan card 24, it may be set in a connection request scan mode to wait for a connection request transmitted by the master wireless device 3. Upon detecting a connection request by the master device 3, the selected data card transmit a connection response back to the master device 3 and a wireless data connection may be established between the selected data card on the access point 1, and the mobile master device 3. The data card and the master device 3 are both in an active mode to allow payload data to be transferred bidirectionally after a wireless connection is established.

To ensure that the selected data card and the master device 3 are aware of each other's Bluetooth™ address in order to use the correct frequency hopping sequences and the time slots, the address of the master device 3 may be encapsulated in the connection request to the access point 1, and the address of the selected data card is encapsulated in the connection response transmitted to the master device 3. After both the selected data card and the master device 3 are set in the active mode, digital data may be transferred bi-directionally between the selected data card of the access point 1 and the master device 3. Meanwhile, the inquiry scan card 24, which may be set in the inquiry scan mode, waits for another inquiry which may be transmitted by another master wireless device 3 that has moved into the range of communication with the access point 1.

FIG. 5 shows a flowchart illustrating one embodiment of an initial procedure for performing data card inquiries by the inquiry scan card 24 of the access point 1. Upon

boot up, the inquiry scan card 24 may detect each of the data cards connected to the slots of the backplane 2. Then the inquiry scan card 24 may query the detected data cards for information including their Bluetooth™ addresses. Each data card may respond with its Bluetooth™ address and clock offset, and the inquiry scan card 24 may log the responses from all data cards into an internal table for future reference.

In one embodiment, the table stored in the inquiry scan card 24 includes entries of the Bluetooth™ address, clock offset, and the number of active connections of each data card. The Bluetooth™ address of a data card is only read after the data card is inserted into a card slot of the backplane 2. An empty card slot does not have a Bluetooth™ address. The clock offset of each data card is the phase offset between the data card and the inquiry scan card 24. For example, each data card may have a 28-bit counter, which is sourced by the clock provided by the inquiry scan card 24. All of these counters thus have the same frequency but different offsets. The clock offset is read only after a data card is inserted. The number of active wireless data connections may be updated as connections are set up and torn down. As described above, the Bluetooth™ address and the clock offset of a given data card may be used to compose the Bluetooth™ FHS packet for the data card.

FIG. 6 shows a diagram illustrating multiple master devices 3 supported by an access point 1 which includes a plurality of data cards forming a plurality of separate piconets. In one embodiment, the first data card 18, which communicates with a first master 86, may serve as the master of a first piconet 88. In a similar manner, the second data card 20 and a second master 90 together may form a second piconet 92. The third data card 22 may be assigned to maintain wireless data connections with two masters 94 and 96 using time division multiplexing, thereby forming a third piconet 98. Although each data card may be assigned to communicate with no more than one master device 3, the access point 1 may be capable of handling communications with more master devices 3 than the number of data cards available on the backplane 2, by balancing the communication loads of the data cards and by prioritizing the master devices 3 if necessary.

Because each data cards of the access point 1 may operate as a separate master device using a common clock signal with different clock offsets, the problem of synchronization in conventional Bluetooth™ networks can be avoided. Furthermore, an

access point 1 which is equipped with a plurality of data cards is capable of handling a plurality of time division multiplexed data links with multiple master devices 3. If the communication loads among the data cards are unbalanced, the inquiry scan card 24 of the access point 1 is capable of reassigning the data links to different data cards in one embodiment to allow the available bandwidths of all of the data cards to be efficiently utilized. Furthermore, connection latency can be reduced if none of the data cards of the access point 1 is overburdened with the need to maintain time division multiplexed data links with too many master devices 3.

The access point 1 has a wide variety of applications in various environments including fixed and mobile locations. For example, the access point 1 can be implemented in an automobile, a home, an office, or a public facility to provide instant access to Internet applications. The access point 1 can also be used to control an array of field sensors in test and measurement applications. For example, the uplink card of the access point 1 can be used to report regular measurements from all sensors acting as masters within the range of communication with the access point 1, to a desired destination through a private network or the public internet.

The present invention has been described with particular embodiments thereof, and numerous modifications can be made which are within the scope of the invention as set forth in the claims.

Claims

What is claimed is:

1. An access point, comprising:

a plurality of circuits capable of communicating with a plurality of piconets respectively, each of the circuits having a unique address and capable of performing a connection response upon detecting a connection request from a requesting piconet to establish a data connection; and

an inquiry scan circuit connected to the circuits, the inquiry scan circuit capable of detecting an inquiry from the requesting piconet, and upon detecting the inquiry, performing an inquiry response and instructing one of the circuits to wait for the connection request.

2. The access point of claim 1, further comprising a connector connecting the circuits and the inquiry scan circuit.

3. The access point of claim 1, wherein the inquiry scan circuit selects one of the circuits suitable to accept the data connection upon detecting the inquiry and instructs the selected circuit to wait for the connection request.

4. The access point of claim 1, wherein each of the piconets includes at least one master device in communication with a respective circuit.

5. The access point of claim 4, wherein the inquiry scan circuit assigns data connections with master devices to the circuits.

6. The access point of claim 4, wherein the inquiry is performed by the master device, and wherein the inquiry response is received by the master device.

7. The access point of claim 4, wherein the connection request is performed by the master device in response to detecting the inquiry response, and wherein the connection response is received by the master device.

8. The access point of claim 1, wherein the inquiry scan circuit comprises a clock connected to provide a common clock signal to the circuits.

9. The access point of claim 8, wherein the inquiry scan circuit and the circuits each comprise a baseband circuit connected to receive the common clock signal.

10. The access point of claim 8, wherein each of the circuits has a unique clock offset, and wherein each of the circuits has a frequency hopping sequence derived from the address and the clock offset of the circuit.

11. The access point of claim 10, wherein the inquiry scan circuit is capable of storing the address and the clock offset of each of the circuits.

12. An access point, comprising:

a plurality of data circuits capable of communicating with a plurality of piconets respectively, each of the data circuits having a unique address and capable of performing a connection response upon detecting a connection request to establish a wireless data connection; and

an uplink circuit connected to the data circuits, the uplink circuit including a physical interface bearing an Internet protocol to a network.

13. The access point of claim 12, wherein the uplink circuit comprises an additional data circuit.

14. The access point of claim 12, wherein the uplink circuit comprises an inquiry scan circuit capable of detecting an inquiry, and upon detecting the inquiry, performing an inquiry response and sending a message to one of the data circuits to wait for the connection request.

15. The access point of claim 14, wherein each of the data circuits is capable storing software and version information for the software.

16. The access point of claim 15, wherein the inquiry scan circuit, upon boot up, queries the version information from the data circuits, validates the version and updates the software of the data circuits as necessary.

17. The access point of claim 12, further comprising an additional uplink circuit including a physical interface bearing an internal protocol to access a secondary network.

18. The access point of claim 12 for use in an automobile, wherein the uplink circuit is capable of accessing Internet wirelessly.

19. The access point of claim 12 for use at a fixed site, wherein the uplink circuit is capable of accessing Internet through a wired connection.

20. The access point of claim 12 for use at a fixed site, wherein the uplink circuit is capable of accessing Internet wirelessly.

21. The access point of claim 12 for controlling an array of field sensors, wherein the uplink circuit is capable of reporting measurements from the field sensors through the network.

22. An access point, comprising:

a connector having a clock interface and a plurality of connections, the clock interface capable of receiving a common clock signal to provide a clock reference to the connections;

a plurality of circuits connected to at least some of the connections of the connector, each of the circuits having a unique address and capable of performing a connection response upon detecting a connection request to establish a data connection; and

an inquiry scan circuit connected to the connector, the inquiry scan circuit capable of detecting an inquiry, and upon detecting the inquiry, performing an inquiry response and sending a message to one of the circuits to wait for the connection request.

23. The access point of claim 22, wherein the data connection comprises a wireless data connection, and wherein each of the circuits is further capable of receiving and transmitting data after the wireless data connection is established.

24. The access point of claim 22 for communication with a wireless device, wherein the inquiry is performed by the wireless device, and wherein the inquiry response is received by the wireless device.

25. The access point of claim 24, wherein the connection request is performed by the wireless device in response to detecting the inquiry response, and wherein the connection response is received by the wireless device.

26. The access point of claim 24, wherein the wireless device is synchronized with the common clock signal.

27. The access point of claim 26, wherein the inquiry scan circuit comprises a clock capable of generating the common clock signal.

28. The access point of claim 26, wherein a frequency hopping sequence of the circuit is derived from the address of the circuit, the common clock signal and a local offset.

29. The access point of claim 23 for communication with a plurality of wireless devices, wherein wireless data connections are established between at least one of the circuits and the wireless devices.

30. The access point of claim 29, wherein each of the circuits has a unique frequency hopping sequence derived from the address of the circuit.

31. The access point of claim 30, wherein the frequency hopping sequence of each of the circuits has a phase derived from the address of the circuit and the common clock signal.

32. The access point of claim 22, wherein each of the circuits is in an idle mode prior to receiving the message from the inquiry scan circuit.

33. The access point of claim 22, wherein the inquiry scan circuit inquires the address of each of the circuits upon boot-up.

34. The access point of claim 33, wherein the inquiry scan circuit is capable of transferring software to upgrade the circuits upon the boot-up.

35. The access point of claim 22 for communication with a wireless device, wherein the inquiry scan circuit is capable of determining which one of the circuits is suitable to accept the data connection upon receiving the inquiry from the wireless device.

36. The access point of claim 35, wherein the circuit suitable to accept the connection is an idle circuit when the inquiry scan circuit receives the inquiry from the wireless device.

37. The access point of claim 35 for communication with a plurality of wireless devices, wherein the inquiry scan circuit is further capable of determining whether communication loads are balanced among the circuits and reassigning the circuits for data connections with the wireless devices based upon a determination that the communication loads are unbalanced among the circuits.

38. The access point of claim 22, wherein the inquiry scan circuit and the circuits transmit and receive signals in a time division multiplexed format.

39. The access point of claim 22, wherein the inquiry scan circuit comprises transmit and receive antenna, and wherein each of the circuits comprises a transmit and receive antenna.

40. An access point for communication with a plurality of wireless devices, comprising:

a connector having a clock interface and a plurality of connections, the clock interface capable of receiving a common clock signal to provide a clock reference to the connections;

a plurality of circuits connected to at least some of the connections of the connector, each of the circuits having a unique address and capable of performing a connection response upon detecting a connection request to establish a wireless data connection with at least one of the wireless devices; and

an inquiry scan circuit connected to one of the connections of the connector, the inquiry scan circuit capable of detecting an inquiry by at least one of the wireless devices, and upon detecting the inquiry, performing an inquiry response, selecting one of the circuits suitable to accept the wireless data connection, and sending a message to the selected circuit to wait for the connection request.

41. The access point of claim 40, wherein the inquiry response is received by the wireless device.

42. The access point of claim 41, wherein the connection response is received by the wireless device.

43. The access point of claim 40, wherein the wireless devices are synchronized by the common clock signal.

44. The access point of claim 40, wherein the inquiry scan circuit comprises a clock capable of generating the common clock signal.

45. The access point of claim 40, wherein a frequency hopping sequence of the circuit is derived from the address of the circuit, the common clock signal and a local offset.

46. The access point of claim 45, wherein each of the circuits connected to the connector has a different local offset.

47. The access point of claim 46, wherein the frequency hopping sequence of each of the circuits has a phase derived from the address of the circuit and the common clock signal.

48. The access point of claim 40, wherein each of the circuits is in an idle mode prior to receiving the message from the inquiry scan circuit.

49. The access point of claim 40, wherein the inquiry scan circuit inquires the address of each of the circuits upon boot-up.

50. The access point of claim 49, wherein the inquiry scan circuit is capable of transferring software to upgrade the circuits upon the boot-up.

51. The access point of claim 40, wherein the circuit suitable to accept the wireless data connection is an idle circuit when the inquiry scan circuit receives the inquiry from the wireless device.

52. The access point of claim 40, wherein the inquiry scan circuit is further capable of determining whether communication loads are balanced among the circuits and reassigning the circuits for wireless data connections with the wireless devices based upon a determination that the communication loads are unbalanced among the circuits.

53. The access point of claim 40, wherein the inquiry scan circuit and the circuits transmit and receive signals in a time division multiplexing format.54. The access point of claim 40, wherein the inquiry scan circuit comprises a transmit and receive antenna, and wherein each of the circuits comprises a transmit and receive antenna.

55. A wireless communications system, comprising:

an access point, comprising: a connector having a clock interface and a plurality of connections, the clock interface capable of receiving a common clock signal to provide a clock reference to the connections; a plurality of data circuits connected to at least some of the connections of the connector, each of the data circuits having a unique address and capable of performing a connection response upon detecting a connection request to establish a wireless data connection;

an inquiry scan circuit connected to the connector, the inquiry scan circuit capable of detecting an inquiry, and upon detecting the inquiry, performing an inquiry response and sending a message to a selected one of the data circuits to wait for the connection request; and

at least one wireless device capable of transmitting an inquiry to notify the inquiry scan circuit of the access point that the wireless device is within communication range to the access point, and transmitting a connection request to request the selected data circuit of the access point to transmit the connection response to establish the wireless data connection.

56. The system of claim 55, wherein the wireless device is synchronized by the common clock signal.

57. The system of claim 55, wherein the inquiry scan circuit comprises a clock capable of generating the common clock signal.

58. The system of claim 55, wherein a frequency hopping sequence of the data circuit is derived from the address of the data circuit, the common clock signal and a local offset.

59. The system of claim 58, wherein each of the data circuits connected to the connector has a different local offset.

60. The system of claim 59, wherein a frequency hopping sequence of each of the data circuits has a phase derived from the address of the data circuit and the common clock signal.

61. The system of claim 55, wherein each of the data circuits is in an idle mode prior to receiving the message from the inquiry scan circuit.

62. The system of claim 55, wherein the inquiry scan circuit inquires the address of each of the data circuits upon boot-up.

63. The system of claim 62, wherein the inquiry scan circuit is capable of transferring software to upgrade the data circuits upon the boot-up.

64. The system of claim 55, wherein the inquiry scan circuit is capable of determining which one of the data circuits is suitable to accept the wireless data connection upon receiving the inquiry from the wireless device.

65. The system of claim 64, wherein the data circuit suitable to accept the wireless data connection is an idle data circuit when the inquiry scan circuit receives the inquiry from the wireless device.

66. The system of claim 55, further including at least one additional wireless device, wherein the inquiry scan circuit is further capable of determining whether communication loads are balanced among the data circuits and reassigning the data circuits for wireless data connections with the wireless devices based upon a determination that the communication loads are unbalanced among the data circuits.67. The system of claim 55, wherein the inquiry scan circuit and the data circuits transmit and receive signals in a time division multiplexing format.

68. The system of claim 55, wherein the inquiry scan circuit comprises a transmit and receive antenna, and wherein each of the data circuits comprises a transmit and receive antenna.

69. The system of claim 55, wherein the inquiry scan circuit comprises a baseband circuit compatible with a Bluetooth™ communications protocol.

70. The system of claim 55, wherein the at least one wireless device is initially a master device.

71. The system of claim 55, wherein the at least one wireless device comprises a plurality of wireless devices, and wherein the plurality of wireless devices are all synchronized with the common clock signal.

72. A method of wireless communication, comprising the steps of:

detecting an inquiry transmitted by a device;

selecting one of a plurality of data circuits to establish a data connection with the device;

transmitting an inquiry response to the device;

detecting a connection request transmitted by the device; and

transmitting a connection response to the device.

73. The method of claim 72, further comprising the steps of:

establishing the data connection between the selected data circuit and the device subsequent to the step of transmitting the connection response; and

transmitting and receiving data subsequent to the step of establishing the data connection.

74. The method of claim 72, further comprising the steps of synchronizing the device and the plurality of data circuits to a common clock signal.

75. The method of claim 74, wherein the selected data circuit is identified by a unique address, further comprising the step of deriving a frequency hopping sequence for the selected data circuit from the address of the selected data circuit.

76. The method of claim 75, further comprising the step of deriving a phase of the frequency hopping sequence for the selected data circuit.

77. The method of claim 74, wherein each of the data circuits is identified by a unique address, further comprising the step of deriving a frequency hopping sequence for each of the data circuits from the address of the data circuit.

78. The method of claim 77, further comprising the step of deriving a phase of the frequency hopping sequence from the address of the data circuit and the common clock signal.

79. The method of claim 72, wherein the steps of detecting the inquiry and transmitting the inquiry response are performed by an inquiry scan circuit connected to the data circuits.

80. The method of claim 79, further comprising the step of sending a message by the inquiry scan circuit to the selected data circuit to notify the selected data circuit to wait for the connection request.

81. The method of claim 80, further comprising the step of setting the data circuits in an idle mode prior to the step of detecting the inquiry.

82. The method of claim 81, further comprising the step of booting up the data circuits prior to the step of setting the data circuits in the idle mode.

83. The method of claim 82, wherein the step of booting up the data circuits comprises the step of inquiring the address of each of the data circuits by the inquiry scan circuit.

84. The method of claim 81, wherein the step of booting up the data circuits comprises the step of transferring software to upgrade the data circuits.

85. The method of claim 79, wherein the step of selecting one of the data circuits comprises the step of determining which one of the data circuits is suitable to accept the wireless data connection subsequent to the step of detecting the inquiry.

86. The method of claim 85, wherein the data circuit suitable to accept the wireless data connection is an idle data circuit when the inquiry scan circuit detects the inquiry from the wireless device.

87. The method of claim 72 for communication with a plurality of wireless devices, further comprising the steps of:

determining whether communication loads are balanced among the data circuits; and

reassigning the data circuits for wireless data connections with the wireless devices in response to the step of determining that the communication loads are unbalanced among the data circuits.

88. The method of claim 79, wherein the data circuits and the inquiry scan circuit are connected to a connector to form a wireless access point to communicate with a plurality of wireless devices, further comprising the step of providing a common clock signal over the connector to the data circuits and the wireless devices.

89. A method of wireless communication, comprising the steps of:

setting a plurality of data circuits in an idle mode;

detecting, by an inquiry scan circuit, an inquiry transmitted by a wireless device;

selecting one of the data circuits to establish a wireless data connection with the wireless device;

transmitting, by the inquiry scan circuit, an inquiry response to the wireless device;

detecting, by the selected data circuit, a connection request transmitted by the wireless device; and

transmitting, by the selected data circuit, a connection response to the wireless device.

90. The method of claim 89, further comprising the steps of establishing the wireless data connection between the selected data circuit and the wireless device subsequent to the step of transmitting the connection response.

91. The method of claim 89, further comprising the steps of synchronizing the wireless device and the plurality of data circuits to a common clock signal.

92. The method of claim 91, wherein the selected data circuit is identified by a unique address, further comprising the step of deriving a frequency hopping sequence for the selected data circuit from the address of the selected data circuit.

93. The method of claim 92, further comprising the step of deriving a phase of the frequency hopping sequence for the selected data circuit.

94. The method of claim 91, wherein each of the data circuits is identified by a unique address, further comprising the step of deriving a frequency hopping sequence for each of the data circuits from the address of the data circuit.

95. The method of claim 94, further comprising the step of deriving a phase of the frequency hopping sequence from the address of the data circuit and the common clock signal.

96. The method of claim 89, further comprising the step of sending a message by the inquiry scan circuit to the selected data circuit to notify the selected data circuit to wait for the connection request.

97. The method of claim 89, further comprising the step of booting up the data circuits prior to the step of setting the data circuits in the idle mode.

98. The method of claim 97, wherein the step of booting up the data circuits comprises the step of inquiring the address of each of the data circuits by the inquiry scan circuit.

99. The method of claim 97, wherein the step of booting up the data circuits comprises the step of transferring software to upgrade the data circuits.

100. The method of claim 89, wherein the step of selecting one of the data circuits comprises the step of determining which one of the data circuits is suitable to accept the wireless data connection subsequent to the step of detecting the inquiry.

101. The method of claim 89, for communication with a plurality of wireless devices, further comprising the steps of:

determining whether communication loads are balanced among the data circuits; and

reassigning the data circuits for wireless data connections with the wireless devices in response to the step of determining that the communication loads are unbalanced among the data circuits.

102. The method of claim 89, wherein the data circuits and the inquiry scan circuit are connected to a common connector to form a wireless access point to communicate with a plurality of wireless devices, further comprising the step of providing a common clock signal to over the connector the data circuits and the wireless devices.

103. A method of wireless communication, comprising the steps of:

detecting, by an inquiry scan circuit, an inquiry transmitted by a wireless device;

selecting one of the data circuits that is most suitable to accept the wireless data connection subsequent to the step of detecting the inquiry, comprising the steps of:

determining whether communication loads are balanced among the data circuits; and

reassigning the data circuits for wireless data connections with the wireless devices if the communication loads are unbalanced among the data circuits;

sending, by the inquiry scan circuit, a message to the selected data circuit that is most suitable to accept the wireless data connection to wait for a connection request;

transmitting, by the inquiry scan circuit, an inquiry response to the wireless device;

detecting, by the selected data circuit, the connection request transmitted by the wireless device; and

transmitting, by the selected data circuit, a connection response to the wireless device.

104. The method of claim 103, further comprising the steps of establishing the wireless data connection between the selected data circuit and the wireless device subsequent to the step of transmitting the connection response.

105. The method of claim 103, further comprising the steps of synchronizing the wireless device and the plurality of data circuits to a common clock signal.

106. The method of claim 105, wherein the selected data circuit is identified by a unique address, further comprising the step of deriving a frequency hopping sequence for the selected data circuit from the address of the selected data circuit.

107. The method of claim 106, further comprising the step of deriving a phase of the frequency hopping sequence for the selected data circuit.

108. The method of claim 103, wherein each of the data circuits is identified by a unique address, further comprising the step of deriving a frequency hopping sequence for each of the data circuits from the address of the data circuit.

109. The method of claim 108, further comprising the step of deriving a phase of the frequency hopping sequence from the address of the data circuit and the common clock signal.

110. The method of claim 103, further comprising the step of setting the data circuits in an idle mode prior to the step of detecting the inquiry.

111. The method of claim 110, further comprising the step of booting up the data circuits prior to the step of setting the data circuits in the idle mode.

112. The method of claim 111, wherein the step of booting up the data circuits comprises the step of inquiring the address of each of the data circuits by the inquiry scan circuit.

113. The method of claim 111, wherein the step of booting up the data circuits comprises the step of transferring software to upgrade the data circuits.

114. The method of claim 103, wherein the data circuits and the inquiry scan circuit are connected to a connector to form a wireless access point to communicate with a plurality of wireless devices, further comprising the step of providing a common clock signal over the connector to the data circuits and the wireless devices.

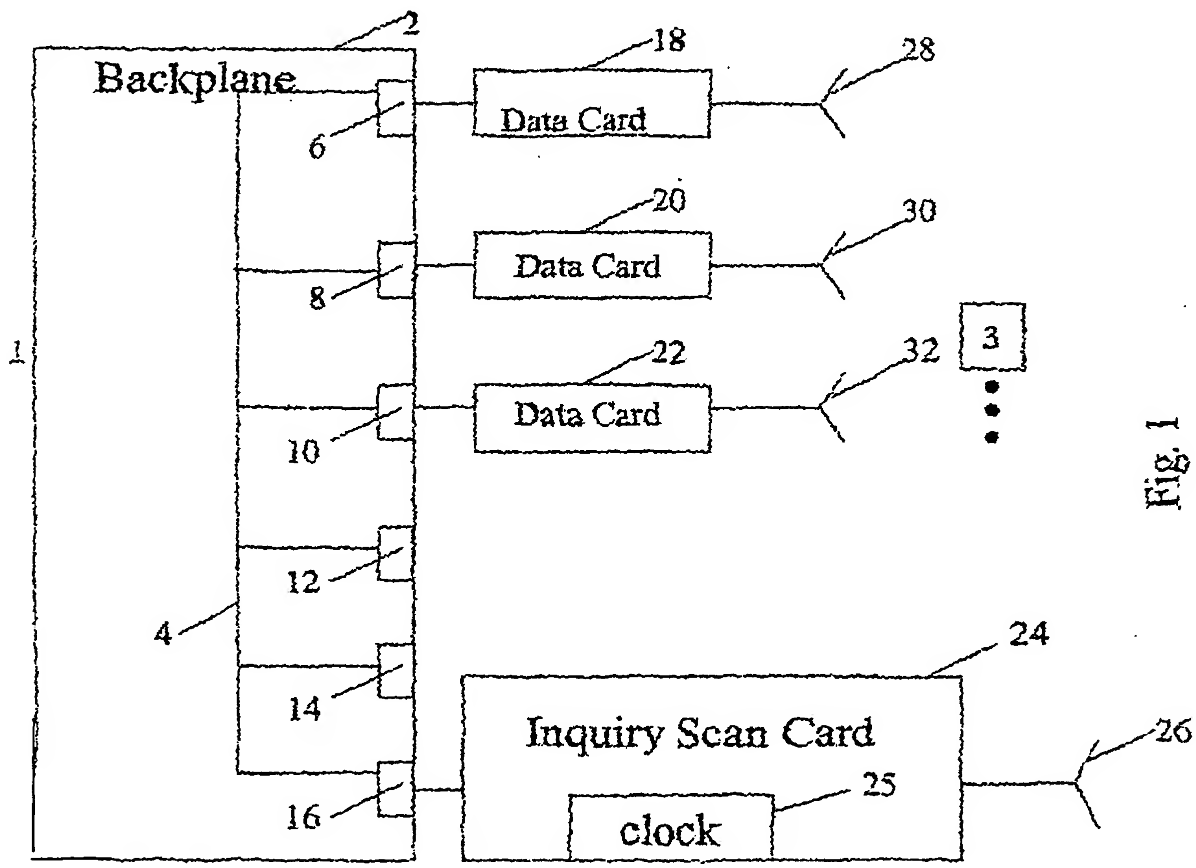
Backplane
Data Card
Data Card
Data Card
Inquiry Scan Card
clock
1
2
3
4
6
8
10
12
14
16
18
20
22
24
25
26
28
30
32

Fig. 1

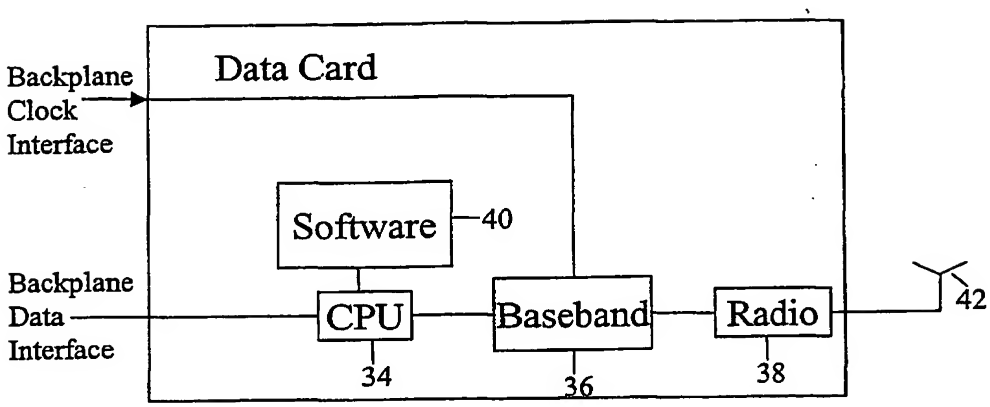
Data Card
Backplane
Clock
Interface
Software
40
Backplane
Data
Interface
CPU
Baseband
Radio
42
34
36
38

Fig. 2

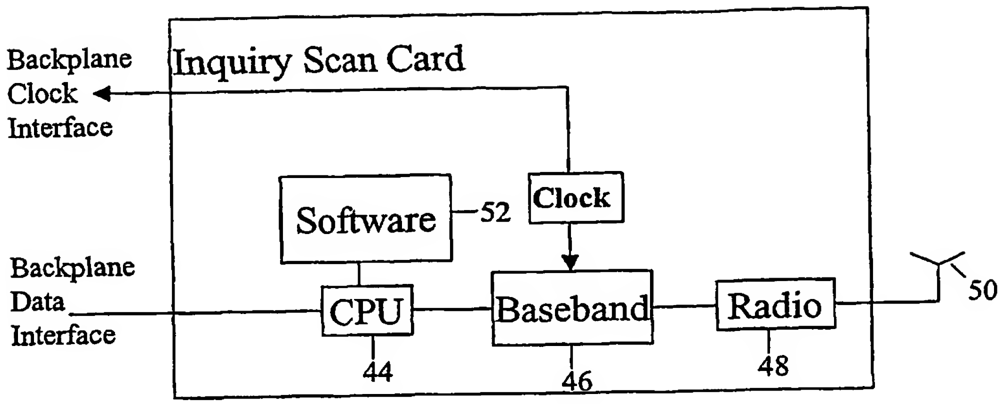
Backplane
Clock
Interface
Inquiry Scan Card
Software
52
Clock
Backplane
Data
Interface
CPU
Baseband
Radio
50
44
46
48

Fig. 3

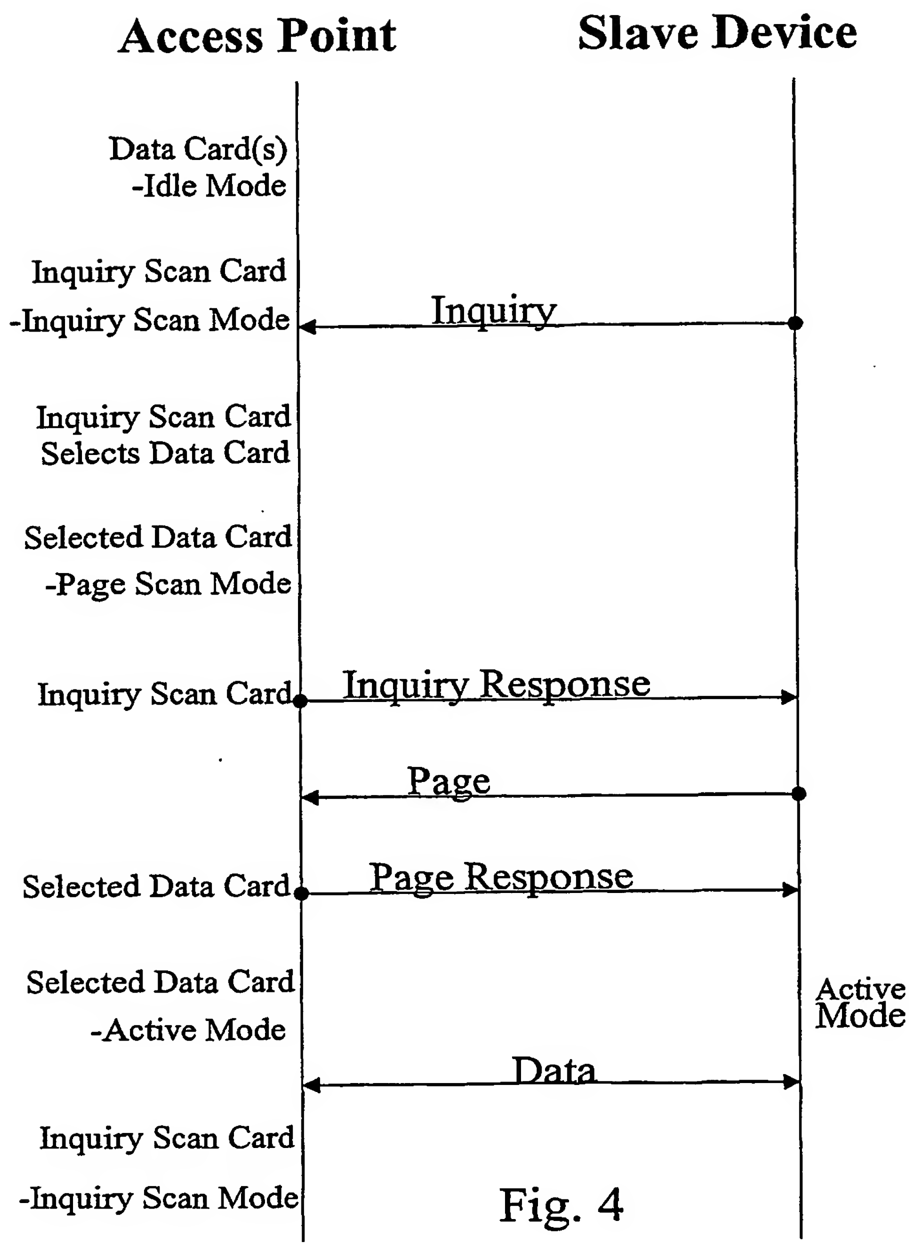
Access Point
Slave Device
Data Card(s)
-Idle Mode
Inquiry Scan Card
-Inquiry Scan Mode
Inquiry
Inquiry Scan Card
Selects Data Card
Selected Data Card
-Page Scan Mode
Inquiry Scan Card
Inquiry Response
Page
Selected Data Card
Page Response
Selected Data Card
-Active Mode
Active
Mode
Data
Inquiry Scan Card
-Inquiry Scan Mode

Fig. 4

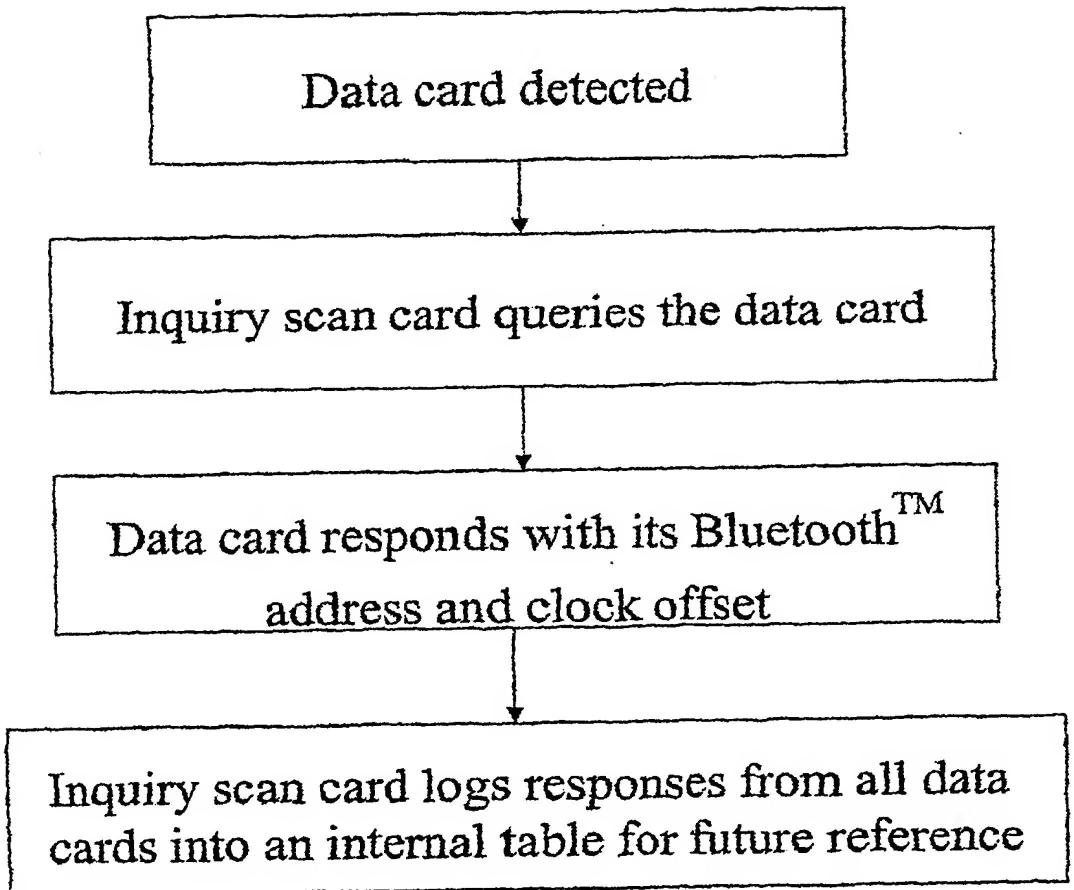
Data card detected
Inquiry scan card queries the data card
Data card responds with its Bluetooth™ address and clock offset
Inquiry scan card logs responses from all data cards into an internal table for future reference

Fig. 5

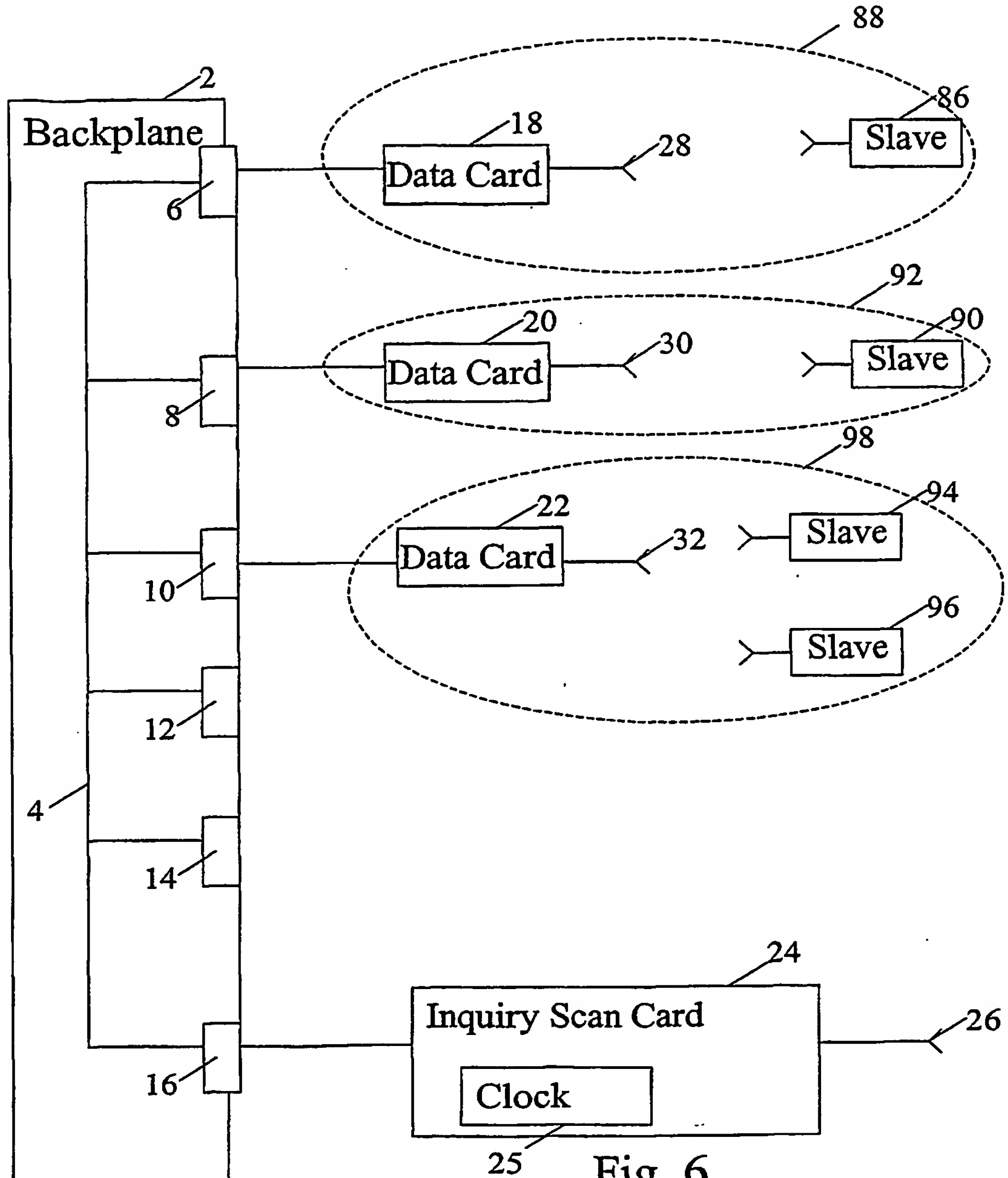
88
2
Backplane
86
18
28
Slave
Data Card
6
92
20
90
30
Data Card
Slave
8
98
22
94
Slave
32
Data Card
10
96
Slave
12
4
14
24
Inquiry Scan Card
26
16
Clock
25

Fig. 6